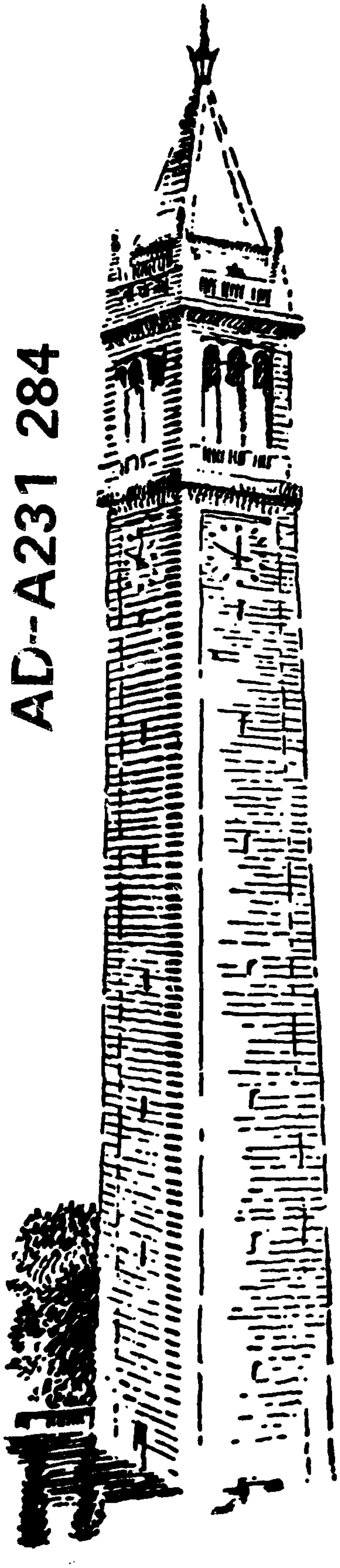

PROGRESS REPORT, 3rd & 4th QUARTER 1988
PLASMA THEORY AND SIMULATION GROUP

Professor C.K. Birdsall

July 1 to December 31, 1988

DOE Contract DE-FG03-86ER53220
ONR Contract N00014-85-K-0809
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ELECTRONICS RESEARCH LABORATORY
College of Engineering
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18. SUPPLEMENTARY NOTES

Our group uses theory and simulation as tools in order to increase the understanding of plasma instabilities, heating, transport, plasma-wall interactions, and large potentials in plasmas. We also work on the improvement of simulation both theoretically and practically.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Research in plasma theory and simulation, plasma-wall interactions, large potentials in plasma.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is a brief progress report, covering our research in general plasma theory and simulation, plasma-wall physics theory and simulation, and code development. Reports written inthis period have been circulated separately. A publications list plus abstracts for two major meeting are included.

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THIRD AND FOURTH QUARTER PROGRESS REPORT
FROM
PLASMA THEORY AND SIMULATION GROUP

July 1 to December 31, 1988

Our research group uses both theory and simulation as tools in order to increase the understanding of instabilities, heating, transport, plasma-wall interactions, and large potentials in plasmas. We also work on the improvement of simulation, both theoretically and practically.

Our staff is:

Professor C.K. Birdsall *Principal Investigator*	191M	Cory Hall	643-6631
Dr. Ian Morey *Post-doctorate*	187M	Cory Hall	642-3477
Mr. Scott Parker	199MD	Cory Hall	642-1297
Mr. Richard Procassini	199MD	Cory Hall	642-1297
Mr. Vahid Vahedi	199MD	Cory Hall	642-1297
Mr. Julian Cummings	199MD	Cory Hall	642-1297
Mr. John Verboncoeur *Research Assistants(students)*	199MD	Cory Hall	642-1297

Our advisers are:

Dr. Ilan Roth *Physicist, Space Science Lab, UCB*	304	SSL	642-1327
Ms. Lou Ann Schwager *Post doc at Sandia Labs, Livermore*		Sandia	
Dr. Bruce Cohen	L630	LLNL	422-9823
Dr. Alex Friedman	L630	LLNL	422-0827
Dr. A. Bruce Langdon *Physicists, Lawrence Livermore Natl. Lab*	L472	LLNL	422-5444

December 31, 1988

DOE Contract DE-FG03-86ER53220
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Thermionics Research and Training Program

ELECTRONICS RESEARCH LABORATORY

University of California
Berkeley, CA 94720

QPR 3 and QPR 4
July 1 to December 31, 1988

This combined Quarterly Progress Report is abbreviated. The research done in this period which has appeared as ERL reports have been circulated. We apologize for mailing this report written well after the work. The time and support needed to produce QPR's as in the past were not available. Also, Prof. Birdsall was Joint Institute of Fusion Theory Visiting Professor at Nagoya University during most of this period.

Our QPR history dates from the late 1960's, and has served us well as a vehicle to communicate our research results and as practice in writing for our research students, prior to journal article and thesis writing. The latter has helped produce an average of 3-5 publications per Ph.D. student at the time of graduation. However, times change, support changes, and emphasis changes.

We list our publications for all of 1988, 1 Journal article, 4 ERL reports, 9 talks and 5 invited talks. Abstracts of the IEEE talks and APS/DPP talks are provided.

Reprints of the Journal article and the ERL reports have already been sent.

C.K. Birdsall
Principal Investigator

Publications for 1988

Journal Articles

Niels F. Otani and Bruce I. Cohen, "Effect of Large-Amplitude Perpendicularly Propagating Radio Frequency Waves on the Interchange Instability," Phys. Fluids, **31**, pp. 158-176, January 1988.

ERL Reports

K. Theilhaber, "Vorte: Formation and Particle Transport in a Cross-Field Plasma Sheath," University of California, Berkeley, Memorandum No. UCB/ERL M88/21, March 20, 1988.

Lou Ann Schwager and C. K. Birdsall, "Collector and Source Sheaths of a Finite Ion Temperature Plasma," University of California, Berkeley, Memorandum No. UCB/ERL M8/23, April 13, 1988.

Lou Ann Schwager, "Effects of Secondary Electron Emission on the Collector and Source Sheaths of a Finite Ion Temperature Plasma," University of California, Berkeley, Memorandum No. UCB/ERL M88/24, April 13, 1988.

Lou Ann Schwager, "Effects of Ion Reflection on the Collector and Source Sheaths of a Finite Ion Temperature Plasma," University of California, Berkeley, Memorandum No. UCB/ERL M88/25, April 13, 1988.

Talks, Conference Proceedings

ICRF/Edge Physics Workshop, March 30-April 1, 1988, Boulder, Colorado.

W. S. Lawson and C. K. Birdsall, "Undriven Plasma Wall Interaction Simulations, Showing Turbulence with and without an Initial Vacuum Gap."

W. S. Lawson and C. K Birdsall, "Antenna Driven Plasma Wall Interaction Simulation, Showing Local Turbulence and About 3 Times Larger Flux to the Wall."

IEEE Conference on Plasma Sciences, June 6-8, 1988, Seattle, Washington.

C.K. Birdsall, "Serendipity is no accident, even in plasma research", Plasma Science and Applications Award acceptance address.

W. S. Lawson, M. A. Lieberman, and C. K. Birdsall, "Electron Dynamics of RF Driven Parallel Plane Reactor."

A. Friedman, S. L. Ray, C. K. Birdsall, and S. E. Parker, "Multi-Scale Particle-in-Cell Plasma Simulation: Timestep Control Criteria and some Tests."

APS Division of Plasma Physics annual meeting, Hollywood, Florida, October 31-November 4, 1988.

S.E. Parker, "A Proposed Particle-In-Cell Method for Modeling Small Angle Coulomb Collisions in Plasmas."

C.K. Birdsall, and W. S. Lawson, "Computer simulation of Plasma Response Near an RF Antenna."

I.J. Morey, R.W. Boswell, and C.K. Birdsall, "Particle Simulation of a Low Pressure RF Discharge."

P.G. Gray, W.S. Lawson, and C.K. Birdsall, "Heat Flow Between Species in a One-Dimensional Simulation Plasma."

Talk

C.K. Birdsall, "Plasma-Sheath-Surface Dynamics via Particle Simulations," June 9-10, 1988, at NSF Workshop on New Directions in Plasma Engineering, UC Berkeley.

Invited Talks (in Japan)

C.K. Birdsall, "Vortex formation and particle transport in a cross-field plasma sheath," (Co-author K. Theilhaber), September 26-27, 1988, at Plasma Sheath and Potential Formation Seminar, Sendai Japan.

C.K. Birdsall, "Plasma sheath small-signal RF impedances as obtained from simulations of a planar device," October 28, 1988, Seminar at Inst. Plasma Physics, Nagoya University, Japan.

C.K. Birdsall, "Source and collector sheaths in a bounded plasma device," (Co-author L.A. Schwager) and "The magnetized plasma sheath interacting self-consistently with an absorbing wall; Kelvin-Helmholtz instability growth with saturation as a dynamic steady state, producing Bohm diffusion," (Co-author K. Theilhaber), December 8, 1988, Inst. of Plasma Physics, Nagoya University, Japan. (The latter also presented at Hiroshima University a week later.)

C.K. Birdsall, "Hands-on demonstration on a personal computer of our periodic code ES1 and of our bounded code PDW1," (Co-author John Verboncoeur) December 9, 1988, Inst. of Plasma Physics, Nagoya University, Japan.

1R 19 **Computer Simulation of Plasma Response Near an RF Antenna.** C. K. BIRDSALL *Electronics Research Lab, U. C. Berkeley* W. S. LAWSON *Courant Institute, New York University* — A two-dimensional electrostatic code is used to investigate the response of a magnetized plasma to RF drive at ion cyclotron frequencies as a function of drive frequency and amplitude. The plasma parameters are chosen to model a Tokamak edge plasma as closely as possible. The electrostatic approximation is of marginal validity, but the results should be indicative of the important effects in the electromagnetic case. The plasma characteristics of interest are the ion flux to the wall, and the energy of the ions that strike the wall. Our initial results show that the flux to the wall increases with the drive amplitude, and that the energy of ions striking the wall is a strong function of frequency. Simulations at a drive frequency of 10/3 of the ion cyclotron frequency showed no increase in temperature, but those at 5/3 showed an order of magnitude increase or more. Further results will be presented.

This work was supported by USDoE contract DE-AC03-87ER53254

2P 15 **Heat Flow Between Species in a One-Dimensional Simulation Plasma.** P. G. GRAY *Dartmouth College*, W. S. LAWSON *Courant Institute, NYU*, and C. K. BIRDSALL *UC Berkeley* — We apply the kinetic theory of a one-dimensional plasma as worked out by Eldridge and Feix [Ref. 1] to the problem of heat flow between species in a simulation plasma. It is necessary to define a simulation temperature which may be very different from the intended physical temperature. Heat flows in accordance with this simulation temperature, allowing heat to flow from one species to another which was intended to be hotter. This effect can be a serious pitfall to simulators who model a minority species as a large number of sub-particles each of which has a fraction of the charge of the particles of the other species.

[1] O. C. Eldridge and M. Feix, Phys. Fluids 6, 398 (1963).

2Q 8 **A Proposed Particle-In-Cell Method for Modeling Small Angle Coulomb Collisions in Plasmas.*** S. E. Parker, *Electronics Research Laboratory, U. C. Berkeley* — We are developing a method to model small angle Coulomb collisions self-consistently. This method may be used in standard PIC plasma simulations to include collisions, or as an alternative to solving the Fokker-Planck equation using finite difference methods. The distribution functions for both ions and electrons are represented by a large number of particles. The particle velocities change as a function of the drag force and the diffusion in velocity, which is represented by a random walk process. This is analogous to previous Monte-Carlo methods[1], except we calculate the drag force and the diffusion tensor self-consistently. The particles are weighted to a grid in velocity space. The associated "Poisson's equations" are solved for the Rosenbluth potentials, from which the drag force and diffusion tensor are obtained. This poster will outline the proposed method.

* Work performed for USDoE under contract FG03-86ER220.

[1] T. D. Ronglien and T. A. Cutler, *Nuclear Fusion* 20, 1003 (1980).

2Q 18 **Particle Simulation of a Low Pressure RF Discharge** I.J. Morey, R.W. Boswell*, C.K. Birdsall, *Electronics Research Laboratory, U. C. Berkeley* — RF discharges have been simulated with a bounded, one dimensional particle-in-cell model which includes both ionization and secondary electron emission. One electrode is grounded and the other is made to oscillate between ±200V with a frequency of 20MHz. The simulations are started with a small number of cold ion and electron pairs and run until equilibrium is reached. At equilibrium the ions and electrons react to the average and instantaneous potentials respectively[1] since $\omega_{pi} < \omega_{rf} < \omega_{pe}$. A greater proportion of the ionization occurs within the sheaths at higher pressure, but there is an optimumpressure at which the highest plasma densities are achieved. It was also found that the discharge could be sustained without any secondary electron emission, and that the effects of secondary electron emission due to the ions decreases with pressure.

* at the Australian National University.

[1] R.W. Boswell and I.J.Morey, *Appl. Phys. Lett.* 52, 21 (1988).

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